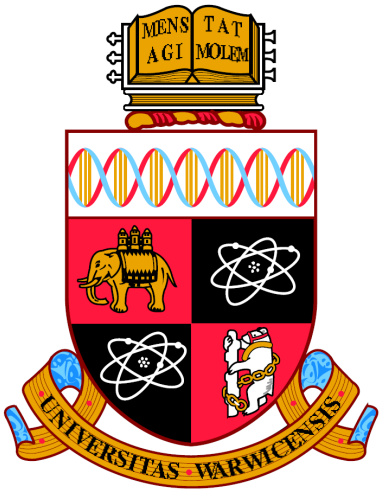


# IMPROVING OUTCOMES FROM MAJOR TRAUMA

by

**Dr Carl McQueen**

**MBChB, DIMC, MMedSci**

Thesis submitted for the degree of

Doctor of Philosophy

**Department of Medicine**

**University of Warwick**

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# CONTENTS

# ABBREVIATIONS

| | | |
|---|---|---|
| ABCDE | – | Airway, Breathing, Circulation, Disability, Exposure |
| CAD | – | Computer Assisted Dispatch |
| CCP | – | critical care paramedic |
| ECT | – | Enhanced Care Team |
| ETC | – | European Trauma Courses |
| GRADE | – | Grades of Recommendation, Assessment, Development and Evaluation |
| HEMS | – | Helicopter Emergency Medical Service |
| JRCALC | – | Joint Royal Colleges Ambulance Liaison Committee |
| MERIT | – | Midlands Air Ambulance and West Midlands Medical Emergency Response Intervention Team |
| MIMMS | – | Major Incident Medical Management and Support |
| MTC | – | major trauma centre |
| MTN | – | Major Trauma Network |
| NCEPOD | – | National Confidential Enquiry into Patient Outcomes and Death |
| NHS | – | National Health Service |
| NIHR | – | National Institute for Health Research |
| PRISMA | – | Preferred Reporting Items for Systematic Reviews and Meta-Analyses |
| RSI | – | rapid sequence induction |
| TARN | – | Trauma Audit and Research Network |
| WMAS | – | West Midlands Ambulance Service |

# ACKNOWLEDGEMENTS

Thesis overview and summary prepared by Professor Gavin Perkins. Dr Carl McQueen was supervised by Professor Gavin Perkins, Dr Ric Crossman and Professor Matthew Cooke.

# DECLARATION

This thesis is submitted to the University of Warwick in support of an application for the degree of Doctor of Philosophy. It has been composed by Dr Carl McQueen and his supervisors and has not been submitted in any previous application for any degree.

The work presented (including data generated and data analysis) was carried out by Dr Carl McQueen.

Gavin Perkins pp Carl McQueen
30th day of September 2016

# ABSTRACT

This thesis presents work from six papers written by the late Dr Carl McQueen during his time as a National Institute for Health Research Doctoral Research Fellow working at the University of Warwick. It explores how best to improve the outcomes of patients who sustain major trauma in the UK – something McQueen was passionate about.

Mobile enhanced care teams can bring the specialist skills usually limited to a hospital to the patient's side at the point of injury. One of the key specialist interventions such teams can provide is prehospital anaesthesia. In a retrospective observational study from a regional enhanced care team, McQueen showed that prehospital anaesthesia was delivered with a high success rate to patient who sustained major trauma and were unconscious, with or without airway compromise.

The decision about when to send an enhanced care team to the scene of an emergency is challenging. Often insufficient information is available about the nature of the victim's injury or illness to make an informed decision. McQueen showed that it was relatively rare for patients with medical problems or those linked to equestrian incidents to require specialist intervention. McQueen also showed the location of patients requiring enhanced care skills varies by time of day with most incidents at night occurring around cities / large towns. A systematic review of the literature found little evidence to guide decision making for primary dispatch of the enhanced care teams. Despite the paucity of evidence for triage systems to inform dispatch of enhanced care teams, reorganisation of regional trauma services in the West Midlands appears to have improved targeted dispatch of enhanced care teams.

Together these papers show the potential for benefit from better co-ordination of enhanced care teams.

# A VISION

"My passion for research in Prehospital and Emergency Care was forged during my undergraduate training. As a student I volunteered with a charity providing medical cover at mass gatherings and I became fascinated by service organisation and targeting of care and resources to patients in greatest clinical need. As an undergraduate I designed and led a number of research projects analysing the operational effectiveness and organisation of medical teams at mass gathering events. The results of this work resulted in the design and implementation of modified training programmes for medical students deployed within medical teams at mass gatherings. Research that I led into improvements in operational efficiency and patient care at events resulted in revised deployment policies for integrated medical teams. I embraced opportunities to disseminate the results of my work at a number of national and international conferences, most notably in Singapore, Norway and the Czech Republic. A study that I designed and led analysing the care provision for children at a large mass gathering event in the UK has been published in a peer review journal. Whilst developing my interest in research as a student I remained focused on my studies, maintaining an excellent academic record being awarded a number of medical school prizes and distinctions and an MBChB with honours.

I continued to pursue my passions during my postgraduate training in Emergency Medicine, becoming inspired by the challenges of system organisation and care delivery in busy Emergency Departments. As a clinician working in front line areas of the National Health Service I derive great personal and professional fulfilment from actively embracing the responsibility to ensure that high standards of clinical care and service are provided for patients when they are most vulnerable. I have sought opportunities for research in order to improve clinical care and service delivery in the departments in which I have worked. I have presented the results of a number of audits and prospective observational studies related to care provision and service delivery, at over a dozen national and international Emergency Medicine conferences throughout the United Kingdom and Europe. The results of some of these projects have also been published in peer review publications in Emergency Medicine.

As I have worked to develop clinical skills and experience as a provider of Emergency and Prehospital trauma care I have sought to embrace opportunities to promote the dissemination of high quality evidence from research to my professional peers. I am an instructor for the Major Incident Medical Management and Support (MIMMS) and European Trauma Courses (ETC) which provide me with opportunities to assist others with the development of their skills and ensure that the latest developments in trauma care are promoted so that they can influence practice. Alongside other experienced providers of trauma care from across Europe I have co-authored chapters of the new ETC manual due for publication in 2013. I have also contributed to the on-going development of Prehospital Emergency Medicine through co-authorship of the Prehospital Care chapters of the Oxford Handbook of Trauma Critical Care that is due for publication in spring 2013, and by taking an active role in the development of the training programme for Prehospital Emergency Medicine in the West Midlands Deanery.

I have over a decade of experience with working within Prehospital Care systems in the UK and have a Diploma in Immediate Medical Care from the Royal College of Surgeons of Edinburgh. Since August 2012 I have been a member of the Midlands Air Ambulance and West Midlands Medical Emergency Response Intervention Team (MERIT) schemes and actively participate in the delivery of Prehospital care within the West Midlands Major Trauma Network (MTN).

Recently, I completed a Master's degree in Medical Education at the University of Nottingham, further augmenting my skills in both research and education. I am experienced in the analysis and interpretation of qualitative and quantitative studies and designed and led a project to develop a training tool to improve decision making in the time critical environments encountered in Emergency and Prehospital Care. This research project involved analyses of the knowledge skills and attitude frameworks of fellow professionals employed in time critical environments and the establishment and refinement of shared cognitive pathways within teams, through structured interviews and small group feedback. The feasibility and validity of the training tool were assessed using quantitative feedback methods. I have passionately explored opportunities to disseminate the research findings and I am due to present the results at the TRAUMACARE Conference (UK) in the spring of 2013 as an invited speaker. The Masters degree was awarded with

distinction and provides me with a strong foundation of knowledge and experience in the areas of decision making and clinical reasoning that will be further enhanced by completion of this PhD project.

Since August 2012 I have been employed as a Research Fellow in the Heart of England National Health Service (NHS) Trust and the University of Warwick working under the tutelage of Professors Gavin Perkins and Matthew Cooke. The University of Warwick have an established pedigree in research into Emergency and Prehospital Care systems and hosts the guidelines committee of the Joint Royal Colleges Ambulance Liaison Committee (JRCALC) that publishes the clinical guidelines used by Ambulance Service personnel throughout the United Kingdom. In the last year the University handled projects relating to £97 million pounds of research income.

I have used this post to build on the foundations established in the early years of my training and will utilise the guidance and support offered by tutors who are leaders in the field of research to support my own development as an independent researcher. I have embraced opportunities to undertake preparatory work analysing the operational efficiency of resource deployment within the West Midlands Major Trauma Network that I presented at the recent Association of Air Ambulances Conference in Telford (UK) as an invited speaker. I aim to build on this experience to realise my potential to become an independent leading researcher capable of providing high quality evidence that will inform clinicians involved in trauma care around the world and improve patient care through advances in practice.

The award of this National Institute for Health Research (NIHR) Doctoral Research Fellowship will enable me to achieve my goal of becoming an independent research lead dedicated to providing high quality evidence that will inform clinicians and improve care standards patients with life-threatening and severe injuries and reduce preventable death and permanent disability following trauma."

Dr Carl McQueen, January 2013

# OBITUARY

*BMJ* 2016;353:i3332 doi: 10.1136/bmj.i3332



OBITUARIES

# Carl McQueen

Gavin Perkins, Samantha Brace-McDonnell

Carl McQueen trained to be a doctor in Leeds and graduated with honours in 2005. He achieved no fewer than 10 prizes and distinctions during his time at medical school. From his early days at medical school Carl developed a passion for medicine at the sharp end. He joined the St John Ambulance as a volunteer and provided medical cover at mass gatherings, such as concerts and sports events. After leaving medical school he started training in emergency medicine, undertaking rotations in anaesthesia, critical care medicine, and emergency medicine in the Leeds and Nottingham area. Having obtained membership of the Royal College of Emergency Medicine in 2009 and the diploma in immediate medical care in 2010, he obtained a chancellor's scholarship from the University of Warwick, to enable him to start on his PhD studies. He developed an ambitious research programme designed to establish the best ways to identify patients who would benefit from the advanced skills that he and his colleagues in the air ambulance could bring. This allowed him to obtain a highly competitive and prestigious PhD fellowship from the National Institute for Health Research.

Not satisfied with working as a full time researcher, Carl continued to want direct contact with patients, which he pursued between work at Solihull and Derby hospitals, and with Midlands Air Ambulance.

Beyond his passion for his clinical and research work, Carl was always generous with sharing his knowledge, skills, and expertise to support colleagues either informally or in his role as leader for the advanced emergency practice masters module. Applying the skills he'd learned while doing his masters degree in medical education, he trained and supported many of his colleagues in emergency medicine and prehospital care to deliver evidence based treatments to the patients they served.

Carl had a wide and growing network of collaborators, included the Trauma Audit Research Network, NHS Pathways, NHS England, Department of Health, European Resuscitation Council, and International Liaison Committee for Resuscitation and European Trauma Network. His sphere of influence was growing day by day. His research and contribution are recognised and acknowledged at the highest levels within the NHS.

Carl wrote one time: "I continued to pursue my passions during my postgraduate training in emergency medicine, becoming inspired by the challenges of system organisation and care delivery in busy emergency departments. As a clinician working in frontline areas of the NHS I derive great personal and professional fulfilment from actively embracing the responsibility to ensure that high standards of clinical care and service are provided for patients when they are most vulnerable."

Carl left us in the prime of his life, but his short time with us has made an indelible mark. A passionate, bright, caring, and exceptionally hardworking clinician, researcher, and teacher—this is the Carl McQueen whom those of us who worked with him knew and loved. He leaves a legacy through each and every patient in whom his clinical care made a difference, through the services he helped to shape and improve, the many research articles he published, and through the colleagues he taught, supported, and inspired.

Carl leaves his beloved wife, Kirsty; two children, Eliza and Leo; his parents; and two siblings.

## Biography

NIHR clinical doctoral fellow and emergency medicine trainee (b 1981; q Leeds 2005; MCEM, Dip IMC RCS Ed, MMEDSci (Dist)),

# INTRODUCTION

This section aims to provide an overview of the clinical area addressed in McQueen's thesis. It is drawn primarily from work written by McQueen during the course of his PhD and has been posthumously edited by his PhD supervisors for presentation in this thesis.

## 1.1 MAJOR TRAUMA EPIDEMIOLOGY AND OUTCOME

Trauma is the leading cause of premature death across all age groups in England, with over 10,000 cases annually.[1-3] The incidence of trauma among the young is high with an average of 36 life-years lost in each trauma death.[4] Trauma also has a large socio-economic burden because for every trauma death there are approximately two survivors with permanent disability.[5] In addition to the physical effects following severe traumatic injury, survivors often suffer from significant psychological sequelae including anxiety, depression and post-traumatic stress disorder.[6] The associated loss of productivity and socio-economic factors associated with morbidity following significant trauma result in a high burden of disease within populations. The estimated annual cost of major trauma to the NHS in England is between £0.3-0.4 billion.[2] Annual lost economic output resulting from major trauma is estimated to be between £3.3 and £3.7 billion.[7] Compared to other European countries the United Kingdom (UK) has historically had considerable levels of avoidable death and disability following trauma.[8-12]

## 1.2 CENTRALISATION OF SERVICES

The requirement for centralisation of care for patients with severe injury at specialist hospitals was identified in the United States in the 1970s.[13] The earliest evidence to support the centralisation of trauma care was derived from an analysis of the rate of preventable deaths between two counties in California in the late 1970s. West and colleagues compared outcome data for trauma patients in San Francisco

County, where a single specialist hospital was responsible for all trauma care, with those in the neighbouring Orange County, where more than 40 centres managed trauma patients.[14] During the period evaluated San Francisco County was shown to have significantly fewer preventable deaths due to trauma. Trauma care services were subsequently reconfigured in Orange County leading to a reduction in the number of preventable trauma deaths.[15] The development of regionalised trauma systems continued to evolve across the United States during the 1980s and a national framework for trauma care services was established in the early 1990s.[16-19] In the following two decades regionalised trauma systems, based on the model pioneered in the United States, have been established in Australia[20,21] and mainland Europe.[22]

The structure of regionalised trauma systems typically involves the designation of at least one specialist hospital within a geographical area that is appropriately equipped and staffed to provide definitive care for severely injured patients. Such hospitals are commonly referred to as Level 1 trauma centres and provide 24 hour access to specialist led care in a range of essential disciplines including Emergency Medicine; Anaesthesia; Surgery; Radiology and Intensive Care Medicine. Level 1 centres can cover large geographical areas and may be supported by regionalised networks of satellite hospitals which can act as initial receiving centres for patients with severe injury. Following initial stabilisation patients should then be transferred to a trauma centre for definitive management and on-going care.[17]

The impact of regionalised trauma systems on improving the outcome of patients following severe trauma has been extensively investigated.[23] Meta-analysis has shown a 15% reduction in mortality due to trauma due to care in regionalised systems[23] and evidence is emerging of improved functional outcomes for patients managed at centres that provide 24 hour access to specialist trauma services.[24-26]

## 1.3 TRAUMA CARE IN THE UK

In 2007, the National Confidential Enquiry into Patient Outcomes and Death (NCEPOD) investigated the process and outcomes of patients who sustained major trauma. This report identified fundamental deficiencies in the quality and co-

ordination of trauma care in the UK.[2] In contrast to regionalised systems in other developed countries the report highlighted an absence of organised frameworks for the management of patients with severe injury, with up to 60% receiving care that was considered to be suboptimal.

In regionalised trauma systems in Europe[27-30] prehospital care models frequently involve attendance at scene by physicians specially trained in the delivery of time-critical interventions required for initial stabilisation of patients with severe injuries. Poor integration of prehospital services with wider trauma systems was highlighted in the UK as reasons for limitations in access to specialist physician-led care in the early phases following severe injury. Additionally a lack of accurate triage and bypass protocols within ambulance services commonly resulted in transfer of patients to hospitals that did not have the appropriate capabilities. Levels of consistency in the clinical response provided within hospitals, notably the availability of dedicated trauma teams and involvement of consultants, were also highlighted to be poor.

The NCEPOD report made recommendations to address these issues including the provision of Major Trauma Centres, with centralisation of expertise and resources as part of inclusive trauma systems. With detailed planning, regional trauma networks went live across England in April 2012.

## 1.4 PREHOSPITAL CARE FOR MAJOR TRAUMA

Patients suffering severe injuries should be identified early in their care journey to ensure that they access specialist services as quickly as possible. Emergency calls to Ambulance Services are handled by specially trained staff that deploy the nearest appropriate resource to the patient. In the majority of cases this will include an ambulance with a state registered paramedic. The most severely injured, with the greatest risk of death following trauma may benefit from treatment from specialist resources prior to hospital arrival.[31] Early specialist intervention from experienced prehospital doctor-led teams has been shown to reduce mortality by up to 35% in both retrospective and randomised controlled trials.[32,33] Interventions such as

emergency anaesthesia when performed in the prehospital phase of care rather than after arrival at hospital significantly reduce the risk of death, and reduce levels of disability in survivors, especially in head injuries.[34,35] An extra two to six trauma patients survive for every 100 receiving on-scene specialist resource care compared to those who do not.[36]

Specialist Prehospital Care resources are valuable but scarce, sometimes operating independently from Ambulance Services.[37] Some resources are provided by charitable organisations involving volunteer doctors on an ad-hoc basis with varying levels of training and clinical governance.[38] Some organisations such as Air Ambulances do not operate at night or in adverse weather. Access to specialist resources by Ambulance Services can often therefore be limited and, in the case of helicopter schemes, costly.[39]

Given the potential clinical benefits offered by specialist resources at incidents it is fundamental that robust systems exist ensuring that Ambulance Services can rapidly identify cases where they are required.

In conclusion, as the NHS continues with the development of integrated trauma care systems it is timely to look at some of the characteristics of the care systems provided and to explore ways in which system organization may be optimized.

# THESIS OVERVIEW

This thesis presents the findings from six papers undertaken by McQueen during the period of his doctoral study. A brief summary of each paper is presented with the full text appearing in the appendix. The papers focus on the prehospital organization and management of major trauma and cover the following areas:

- Advanced airway care (paper 1): Prehospital anaesthesia performed by physician/critical care paramedic (CCP) teams in a major trauma network in the UK: a 12 month review of practice
- The role of specialist teams in managing medical emergencies (paper 2): Medical Emergency Workload of a Regional UK HEMS Service
- Considerations for remote incidents (paper 3): Utilisation of a Helicopter Emergency Medical Service (HEMS) for equestrian accidents in a regional major trauma network in the United Kingdom
- A role for Helicopter Emergency medical Service (HEMS) at night (paper 4): Enhanced care team response to incidents involving major trauma at night: Are helicopters the answer?
- Effectiveness of major trauma triage systems (paper 5): Does the use of dedicated dispatch criteria by Emergency Medical Services optimise appropriate allocation of advanced care resources in cases of high severity trauma? A systematic review
- Effect of major trauma networks on HEMS operations (paper 6): Impact of introducing a major trauma network on a regional helicopter emergency medicine service in the UK

The first two papers address aspects of specialized care delivered by enhanced care teams. Papers three and four consider optimal modes for tasking and transport for the enhanced care team to remote incidents and incidents which occur at night. Paper five considers the published literature on triage systems used for enhanced care teams and paper six explores the impact of the reorganization of trauma care services in England on enhanced care team workload. These papers combine to create new

knowledge related to the use of enhanced clinical teams in prehospital care and inform future deployment of these rare and expensive resources.

The papers presented arise from McQueen's work which has been published in the peer reviewed literature. This summary of his work that follows was prepared by his PhD supervisor Professor Perkins. It illustrates the substantial contribution of his work to the generation of original knowledge within the field of trauma care.

To the best of our knowledge, the submitted material as a whole is not substantially the same as published or unpublished material that McQueen has previously submitted, or are currently submitting, for a degree, diploma, or similar qualification at any university or similar institution. The co-authors of the papers presented in this body of work have submitted written declarations confirming that the conception, design, synthesis and initial drafts of all papers were undertaken by McQueen.

## 2.1 ADVANCED AIRWAY CARE

Prehospital anaesthesia performed by physician/critical care paramedic teams in a major trauma network in the UK: a 12 month review of practice. **McQueen C**, Crombie N, Hulme J, Cormack S, Hussain N, Ludwig F, Wheaton S. Emerg Med J. 2015 Jan;32(1):65-9

The systematic approach to the assessment and treatment of the critically ill and injured patient follows the Airway, Breathing, Circulation, Disability, Exposure (ABCDE) approach. Management of the airway is prioritized as obstruction of the airway can lead to rapid deterioration of breathing / ventilation which can in itself compromise the circulation to the point of cardiac arrest. Basic airway management involves simple manual positioning of the airway such as the head tilt / chin lift or jaw thrust. This may be supplemented by the use of simple airway adjuncts such as an oropharyngeal or nasopharyngeal airway. Whilst these techniques are helpful for maintaining airway patency they are ineffective at protecting the lower airway from the risk of aspiration of gastric contents. Although supraglottic airways such as the Laryngeal Mask Airway® and iGEL® provide a degree of lower airway protection, the gold standard for airway protection requires the placement of a cuffed tracheal tube. The presence of upper airway reflexes means that it is rarely possible to pass a tracheal tube without anaesthesia unless the patient is deeply unconscious. However delivering an anaesthetic outside a hospital requires specialist training and skills beyond those held by an ambulance paramedic. Therefore prehospital anaesthesia in the UK is restricted to specialist enhanced care medical teams who have received advanced training in the indications and techniques of rapid sequence induction (RSI) and intubation.

In this paper McQueen explores the indications for and success rate of the West Midlands Medical Emergency Response Incident Team (MERIT) in delivering prehospital anaesthesia. This retrospective study analysed data from the first day a newly commissioned MERIT service commenced and ran over a 12 month period (2012-13).

142 cases were identified through a database search amongst 1619 team activations to 1029 cases attended by the MERIT service. A further 130 cases of intubation without drugs were identified mostly for patients who had sustained a cardiac arrest. The majority of cases requiring prehospital anaesthesia were due to trauma (n=130, 92%) of which road traffic collisions were the most common mechanism of injury. The remaining 12 (8%) patients required anaesthesia for medical emergencies. The commonest reason for RSI was unconsciousness (n=106, 75%), followed by actual or impending airway obstruction (n=14, 10%) and anticipated clinical course / transport considerations (n=11, 7.7%). Overall success rates for intubation at first attempt averaged 88%. MERIT critical care paramedics first attempt success rate exceeded that of MERIT doctors (95% versus 88% respectively).

McQueen goes on to discuss the findings from his study in the context of the published literature. He notes the success rates for the West Midlands MERIT service is as good as or better than those reported by other prehospital teams. The high first intubation success rate of critical care paramedics is noted, although the potential that this may reflect differences in the case mix selected for CCP intubation is considered.

The paper adds to existing knowledge by presenting new information on the indications and success rates for tracheal intubation when performed by enhanced care teams. The higher than expected success rates likely reflect the training and exposure of the enhanced care teams to patients requiring these advanced skills. These findings are particularly important at a time when the use of routine practice of prehospital intubation is being questioned and evaluated in large randomized controlled trials.

## 2.2 ROLE OF SPECIALIST TEAMS IN MANAGING MEDICAL EMERGENCIES

Medical Emergency Workload of a Regional UK HEMS Service. **McQueen C**, Crombie N, Cormack S, Wheaton S. Air Med J. 2015 May-Jun; 34(3):144-8.

This paper explores the effect of major trauma networks on the workload of a regional air ambulance service and highlights that around one quarter of HEMS deployments occur for medical emergencies. Whilst previous studies have identified the potential beneficial effects of deploying HEMS assets to medical emergencies including myocardial infarction, cerebrovascular accident and out-of-hospital cardiac arrest in specific circumstances, there is uncertainty about the requirement for such activations in the UK setting. In this study McQueen analyses the workload due to medical emergencies and evaluates the added value of deploying a specialist enhanced care team to such cases.

Drawing data from the Midlands Air Ambulance Clinical Database over a 2 year period (2012-14), 633 (22%) activations were identified for medical cases amongst an overall workload of 2802 activations. The commonest reason for activation were cardiac arrest (n=199, 32%) chest pain (n=163, 26%), collapse (n=95, 15%) and stroke (n=65, 10%). The likelihood of cancellation prior to arrival was greater if the call occurred as a primary dispatch rather than at the request of an ambulance crew on scene (26% vs. 8%, $P<0.0001$). Overall less than one in ten patients attended by the specialist team received interventions that fall beyond the scope of standard paramedic practice. The HEMS platform enhanced the speed of transfer in 42% of cases, mostly in cases of acute myocardial infarction.

In cardiac arrest, the time taken from collapse until emergency services arrive is of critical importance to the likelihood of survival, so it may be logical to assume that a helicopter would provide a timely response to cardiac arrest. McQueen reports that in no cases were the HEMS crew first to arrive on scene. Initial survival rates (return of spontaneous circulation) from cardiac arrest were similar to the national average (25%). Amongst the 40 patients with return of spontaneous circulation, half were conveyed to hospital by helicopter, potentially opening up access to specialized

cardiac arrest centres. Only a small number required specialist intervention (sedation n=5, rapid sequence induction n=3).

Patients with an obtunded conscious level due to collapse, seizure or stroke received specialist intervention (sedation or rapid sequence intervention) in 28%, 15% and 12% of cases respectively.

For patients with chest pain, the main role of the HEMS team was to convey to a specialist regional centre for on-going care. No patients required specialist interventions.

McQueen argues that it was relatively rare for medical cases to require the specialist skills of the HEMS medical team. With an average mission duration between 60-90 minutes, tying up this specialist resource may limit the capability of the HEMS platform to respond to other incidents where clinical need may be greater. He highlights the key limitations of this study as its retrospective nature, absence of outcome data and adjustments for severity of illness. The paper closes by highlighting the need to develop strategies to optimize the use of enhanced care teams to cases likely to derive maximal benefit from their input.

## 2.3 CONSIDERATIONS FOR REMOTE INCIDENTS

Utilisation of a Helicopter Emergency Medical Service (HEMS) for equestrian accidents in a regional major trauma network in the United Kingdom. **McQueen C**, Crombie N, Cormack S, George A, Wheaton S. Injury. 2015 May; 46(5):781-6.

The utilisation of Helicopter Emergency Medical Services (HEMS) in response to equestrian accidents has been an integral part of operations for many years throughout the UK. The potential logistical benefits of utilising aircraft in such cases seem logical, especially in relatively isolated rural areas, enabling delivery of prehospital care personnel to areas that standard ambulances may have difficulty accessing and as a platform for rapid transfer of patients to hospital.

In this study McQueen conducted a retrospective review of Midlands Air Ambulance activations for equestrian accidents over a 12 month period (2012-13). From a total of 1849 incidents, the team attended 1563 scenes of which 114 (6%) missions were activated for equestrian accidents. The majority of incidents were attended by critical care paramedic aircraft (n=82, 72%) whilst the physician-led aircraft attended 32 cases (28%). Two fifths of activations were primary activations whilst the remainder were at the request of an ambulance crew. Incidents occurred almost exclusively in rural locations (92%).

Extremely small proportions of patients required any form of clinical interventions beyond the scope of the UK JRCALC guidelines for Ambulance personnel in the period analysed. Only three patients (3%) required prehospital RSI and there were no recorded cases of ketamine administration for analgesia/conscious sedation. No other advanced care interventions were required. Approximately two thirds of patients were conveyed by air to hospital. Half the patients conveyed by air were transported to a major trauma centre. The average duration of each mission where the patient was conveyed by helicopter was 90 minutes.

McQueen makes the case that equestrian accidents represent a significant proportion of HEMS missions despite very few patients requiring advanced clinical interventions at scene. The potential logistical benefits of utilising aircraft in such

cases seem logical, especially in relatively isolated rural areas, enabling more rapid transfer of patients to hospital and releasing land based resources to respond to further emergencies. He argues that the challenges faced by both HEMS units and Ambulance Services is how best to balance the need for assistance in cases with challenging access/ egress problems with the requirement to target resources to patients with greatest clinical need. At the present time robust, evidence based tasking criteria that can appropriately and efficiently target deployment of physician-led HEMS resources to cases of severe injury remain elusive. McQueen closes by calling for further research in this area.

## 2.4 A ROLE FOR HEMS AT NIGHT?

Enhanced care team response to incidents involving major trauma at night: are helicopters the answer? **McQueen C**, Nutbeam T, Crombie N, Lecky F, Lawrence T, Hathaway K, Wheaton S. Injury. 2015 Jul; 46(7):1262-9

Challenges exist in how to deliver enhanced care to patients suffering severe injury in geographically remote areas within regionalised trauma networks at night. The physician-led Enhanced Care Teams (ECTs) in the West Midlands region of England do not currently utilise helicopters to respond to incidents at night. Instead a land-based asset that is based in the centre of Birmingham is used to transport the enhanced care team. Whilst night air operations are practiced in many parts of continental Europe, operation of HEMS aircraft at night are associated with notable increases in the risk of accidents and costs. Before investing in night HEMS operations, there is a need to review the location and types of incidents of major trauma which occur at night and might potentially benefit from timely delivery of an enhanced care team.

In this study McQueen describes the remote trauma workload at night within the regional network in terms of incident location; injury profile and patient care needs and discusses various solutions to the delivery of ECTs to such incidents, including assessing the need for helicopter based platforms.

McQueen searched the Trauma Audit and Research Network (TARN) database for cases of major trauma in the West Midlands that were conveyed to hospital between 2012 and 2013. TARN identifies cases as major trauma if (i) the injury severity score is > 15 or (ii) if emergency surgery, admission to intensive care or death occurs within 24 hours of hospital admission. This was complemented by a search of West Midlands Ambulance Service (WMAS) records for cases who died prior to arriving at hospital. Records were then linked with corresponding clinical records from the Computer Assisted Dispatch (CAD) system to enable the geographical location and incident type and interventions provided to be identified.

Over the 12 month period there were 1620 cases of major trauma of which 603 (37%) occurred at night. The most frequent precipitating event for cases of major trauma at night were falls (41%), road traffic collisions (21%) and assaults (10%). An enhanced care team was dispatched to 224 cases (37%) and attended 167 incidents during this period.

Analysis of the 436 cases where no enhanced care team attended, identified that only 36 were more than 45 minutes from a major trauma centre. Amongst this group there were 13 cases where McQueen judged intervention from an enhanced care team may have improved patient outcome.

McQueen develops the argument that the logistical considerations of flying helicopters at night, and the low frequency with which the current land based model fails to capture patients requiring advanced interventions provides limited evidence to support night HEMS operations. He suggests that augmentation of the existing road based model will provide a safer and more effective solution than investing in night HEMS operations.

## 2.5 EFFECTIVENESS OF MAJOR TRAUMA TRIAGE SYSTEMS

Does the use of dedicated dispatch criteria by Emergency Medical Services optimise appropriate allocation of advanced care resources in cases of high severity trauma? A systematic review. **McQueen C**, Smyth M, Fisher J, Perkins G. Injury. 2015 Jul; 46(7):1197-206.

Prehospital enhanced care teams are a scarce resource in the NHS. Optimizing systems to ensure the efficient deployment of such resources are important. Striking the balance between over triage (high sensitivity, low specificity) and under triage (low sensitivity, high specificity) is critically important. Over triage means the limited resource may be deployed to incidents where clinical need is less and therefore unavailable for a more critical event. Under triage will mean that cases requiring specialist intervention are missed.

There are two main types of dispatch used for enhanced care teams – primary deployment (dispatching the team at the time the emergency call is made) versus secondary deployment (dispatching the team after an initial assessment is undertaken by a non-specialist team). Which system is most effective, and which criteria should be used for dispatch is unclear. It is therefore timely that McQueen conducted a systematic review of the worldwide literature to identify evidence for both primary and secondary models in the targeted dispatch of enhanced care teams.

The review which followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) criteria identified 555 papers of which 548 remained after removal of duplicates. After review of titles and abstracts, 45 full text articles were reviewed for eligibility of which 16 were finally included.

The majority of studies originated from the Netherlands (31%) and the United States (26%). All but three of the included studies were observational in design. There was one study that assessed the efficiency of Enhanced Care Team dispatch before and after the introduction of a new protocol. Two studies reported the results of telephone/postal surveys of the dispatch criteria and processes utilised by HEMS services: one pan-European and another solely in the United Kingdom. All of the

included studies were assessed as very low quality according to the Grades of Recommendation, Assessment, Development and Evaluation (GRADE) criteria. As there was marked heterogeneity amongst the included studies prompted McQueen to conduct a narrative synthesis of the findings.

Three main themes emerged from the narrative synthesis.

(1) Initial call handling

Despite its importance as the first step in the chain of resource deployment, only one study examined initial call handling and identification of cases requiring an enhanced care team by emergency dispatchers. In a single centre, prospective observational study in the Netherlands, one fifth of 6000 calls triggered the criteria for enhanced care team, only 14% overall resulted in resource deployment. The reasons for poor compliance included problems with managing call volumes and uncertainty about the effectiveness of the triage tool to identify suitable cases. This is reflected by a cancellation rate of 30% after enhanced care team is dispatched. The authors highlight the need for improvements in the triage tool and better training for the emergency dispatchers.

An alternative model to having general emergency dispatchers handle calls for trauma is to have specially trained clinical staff for suspected major trauma. This model was introduced by the London air ambulance in the early 1990s. A retrospective evaluation of this HEMS desk function showed improved efficiency of primary tasking. A more recent paper from Australia provides further evidence that clinical staff were more effective at identifying patients with severe injuries and HEMS resources were delivered more rapidly to scene.

(2) Dispatch criteria

Throughout Europe, a wide range of primary dispatch criteria are utilised by HEMS units, with considerable variation across regional and international boundaries. Whilst a number of studies detailed the primary dispatch criteria utilised to support primary dispatch of ECTs, the majority provided no analysis of the performance characteristics of the protocols in targeting resource

Three studies supported dispatching on the basis of triggering specific criteria such as ejection from a vehicle, fall from height, accidents involving truck/subway/train/ aeroplane/ship, prolonged extrication time >15 min.

(3) Primary dispatch versus standard models

Finally three studies compared primary (at the time of the call) with secondary dispatch (once the crew had arrived). Primary dispatch allowed resources to reach the patient more quickly (although the time saving was often small) but had higher cancellation rates. Secondary dispatch improved sensitivity and specificity of dispatch. Criteria for cancelling enhanced care teams after dispatch were also developed and showed improved sensitivity (99%) and specificity (54%) than primary dispatch criteria alone.

McQueen draws these findings together to conclude that there is a lack of robust evidence supporting the role of primary dispatch models, which incorporate dedicated criteria, to optimise the deployment of Enhanced Care Teams resources to severely injured patients in prehospital trauma systems. He highlights the limitations of the current evidence base noting the scope of studies focus on specific elements of the chain of resource dispatch rather than the overall process and its efficiency at the system level. He calls for further studies to assess the efficiency of systems at each stage of the dispatch process, highlighting that the results of such studies can guide the development of future dispatch models for cases of high-severity trauma requiring advanced clinical care at scene.

## 2.6 EFFECT OF MAJOR TRAUMA NETWORKS ON HEMS OPERATIONS

Impact of introducing a major trauma network on a regional helicopter emergency medicine service in the UK. **McQueen C**, Crombie N, Perkins GD, Wheaton S. Emerg Med J. 2014 Oct; 31(10):844-50.

The National Confidential Enquiry (NCEPOD) into trauma outcomes highlighted the need for improvements in care standards for patients suffering trauma in the UK. In response to the findings of NCEPOD, trauma care services in the UK have been reorganised. A total of 22 major trauma centres (MTCs) have been established throughout England. Essential services, including neurosurgery, trauma surgery and intensive care specialities, are centralized in regional MTCs to ensure that consultant-led care is available for all patients with traumatic injuries in the region.

In the West Midlands, a regional major trauma network has been established through close cooperation and coordination between the West Midlands Ambulance Service (WMAS) NHS Trust and the regional MTCs. Prehospital care provision was enhanced through the provision of additional training and equipment, and the development of a clinical decision tool to assist paramedics to decide which patients to take to a MTC. In addition a regional trauma desk was established and staffed by critical care paramedics to assist with deployment of specialist assets and provide support and guidance to road based crews.

In this study McQueen explores the impact of introducing the West Midlands major trauma network on the Midlands Air Ambulance activity in the 6 months after its launch by comparing it with activity 6 months prior to the launch.

He reports no significant difference in overall workload (1149 before versus 1006 activations after) of which 814 (71%) and 720 (72%) were for trauma respectively. The proportion of cases where the aircraft was deployed within 3 minutes of the initial call fell slightly after the network launch. Concurrently there was a reduction in the proportion of mission cancellations after the launch of the network (24% versus 19%). Patients were more likely to receive critical care

interventions at the scene or during transfer after launch of the network. Critical interventions included rapid sequence induction, thoracostomies, application of pelvic binders and non-drug assisted intubations. On scene times increased by an average of 5 minutes. In cases of helicopter conveyance, ~70% of patients were transported to an MTC. This remained unchanged after the launch of the network.

McQueen concludes that since the introduction of the West Midlands MTN, tasking of HEMS assets to scenes has changed. Small increases in the length of time taken to deploy HEMS assets have been associated with a reduction in the proportion of mission cancellations. McQueen argues that tasking appears to be better targeted to cases involving significant injury, with a greater number of interventions being performed at the scene by HEMS crews. He highlights a need for more detailed evaluation of patient outcomes to determine the clinical and cost effectiveness of the reconfiguration of trauma services in the West Midlands and identify strategies to optimize the utilisation of HEMS assets within the regional network.

# CONCLUSION

McQueen's productivity through his PhD was exceptional. Making use of routinely available data sources he has built a portfolio of evidence related to regional trauma care in the West Midlands. His work covers interventions delivered by enhanced care teams, appropriate use of specialist resources and evaluation of the impact of the re-organisation of regional trauma networks. Evaluation of the published literature, using his newly acquired systematic review skills identifies the paucity of high quality evidence in this area.

This body of work is submitted for consideration of a PhD by publication as a summary of his substantial contribution to the generation of new knowledge through work that has been published in the peer reviewed literature. It serves as evidence of his huge academic potential and his dedication and commitment to improving systems of care for major trauma.

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## Declaration of contributions

**Paper 1: Prehospital anaesthesia performed by physician/ critical care paramedic teams in a major trauma network in the UK: a 12 month review of practice**

Carl McQueen, Nicholas Crombie, Jonathan Hulme, Stef Cormack, Nageena Hussain, Frank Ludwig, Steve Wheaton

*Emergency Medical Journal* 32 (2015) 65–69

Carl McQueen conceived the paper, worked with co-authors to collate the data, conducted the analyses and drafted the first version of the paper and revised it following critical review by co-authors. He submitted the paper for publication and revised it following comments from peer reviewers. He submitted the final version with approval from co-authors.

**Paper 2: Medical Emergency Workload of a Regional UK HEMS Service**

Carl McQueen, Nick Crombie, Stef Cormack, Steve Wheaton

*Air Medical Journal* 34 (2013) 144-8

Carl McQueen conceived the paper, worked with co-authors to collate the data, conducted the analyses and drafted the first version of the paper and revised it following critical review by co-authors. He submitted the paper for publication and revised it following comments from peer reviewers. He submitted the final version with approval from co-authors.

**Paper 3: Utilisation of a Helicopter Emergency Medical Service (HEMS) for equestrian accidents in a regional major trauma network in the United Kingdom**

Carl McQueen, Nick Crombie, Stef Cormack, Arun George, Steve Wheaton

*Injury* 46 (2015) 781–786

Carl McQueen conceived the paper, worked with co-authors to collate the data, conducted the analyses and drafted the first version of the paper and revised it following critical review by co-authors. He submitted the paper for publication and revised it following comments from peer reviewers. He submitted the final version with approval from co-authors.

**Paper 4: Enhanced care team response to incidents involving major trauma at night: Are helicopters the answer?**

Carl McQueen, Tim Nutbeam, Nick Crombie, Fiona Lecky, Thomas Lawrence, Karen Hathaway, Steve Wheaton

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Carl McQueen conceived the paper, collated the data, conducted the analyses and drafted the first version of the paper and revised it following critical review by co-authors. He submitted the paper for publication and revised it following comments from peer reviewers. He submitted the final version with approval from co-authors.

**Paper 5: Does the use of dedicated dispatch criteria by Emergency Medical Services optimise appropriate allocation of advanced care resources in cases of high severity trauma? A systematic review**

Carl McQueen, Mike Smyth, Joanne Fisher, Gavin Perkins

*Injury* 46 (2015) 1197–1206

Carl McQueen conceived the paper and conducted the literature search with guidance from Sam Johnson (University Librarian). CMQ and MS independently assessed the titles, abstracts and papers for inclusion. Data extraction was performed by a single reviewer (CMQ) using a standardised data collection tool, and verified by one of two reviewers (MS and JF). CMQ assessed the quality of the evidence and synthesized the main findings of the paper to produce the first draft of the paper and revised it following critical review by co-authors. CMQ submitted the paper for publication and revised it following comments from peer reviewers. He submitted the final version with approval from co-authors.

**Paper 6: Impact of introducing a major trauma network on a regional helicopter emergency medicine service in the UK**

Carl McQueen, Nick Crombie, Gavin Perkins, Steve Wheaton

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Carl McQueen conceived the paper, collated the data, conducted the analyses and drafted the first version of the paper and revised it following critical review by co-authors. He submitted the paper for publication and revised it following comments from peer reviewers. He submitted the final version with approval from co-authors.

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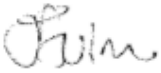

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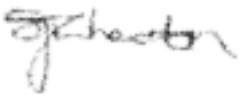

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